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SOURCE ROCK EVALUATION OF ABU GABRA FORMATION IN AZRAG AREA –MUGLAD BASIN, KHARTOUM, SUDAN

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Abstract

The Muglad basin is a large rift basin located in southwestern Sudan. At its nearest point, it lies approximately about 600km southwest of the city of Khartoum. It trends northwest-southeast and consist of a thick Mesozoic and tertiary continental syn-rift sequence buried by a Miocene-Recent post-rift sedimentary cover. These continental sediments comprise fluvial and lacustrine facies. Data from three boreholes, A1, B1, and C1 have been taken up for the present study. The geological associations, the Total Organic Content (TOC) and hydrocarbon generating potential values were studied to evaluate the source rock potential. The evaluation revealed two wells; A1 and C1 to be potential as a source rock in oil and gas generation while the B1 well to be a poor source rock. Abu Gabra1 formation and Intra Abu Gabra formations of A1 well and Intra Abu Gabra 1formation and intra Abu Gabra 2 of C1 well are the most promising.

Keywords: Rift-basin, TOC, Abu Gabra Formation

INTRODUCTION

The Muglad basin is the largest known rift basin which comprises important oil fields in the Sudan interior, where the most significant oil discoveries have been made. The area is approximately bounded by the 32° 00´and 34° 00´ E longitude and 8° 00´ and 11° 30´ N latitudes.(Fig. 1.) It trends NW-SE and the basin measures around 1200 km in length and 300 km in width which is significant compared to the smaller rift basins Melut, White Nile and Blue Nile which are parallel to Muglad basin.

Chevron Company started the first exploration in 1974 and continued its exploration and drilling till 1984.(J.M.Burr and R.O. Collins 2003) After Chevron relinquished the area concession was granted to the Greater Nile Petroleum Operation Company (GNPOC).The main companies in the Sudan oil industry today is the Greater Nile Petroleum Operation Company (GNPOC), China National Petroleum Company (CNPC), Malaysian PETRONAS Company, India National Company and Sudanese Petroleum Company (Sudapet).

The present topic is particularly interesting since the Muglad sedimentary basin is characterized by thick continental clastic sequences of Jurassic, Cretaceous and Tertiary age, based on seismic data and well control, (Schull, 1988; Wycisk et al., 1990). Over 13,716m of sediments was deposited in the deepest part of the Muglad basin, which is Kaikang Trough. However the maximum drilled thickness of sediments in the Muglad Basin does not exceed 4545m.

Data from the three exploration wells A-1, B-1, and C-1 have been studied geologically and geochemically. Though significant discoveries have been established a lot more unexplored wells exist.

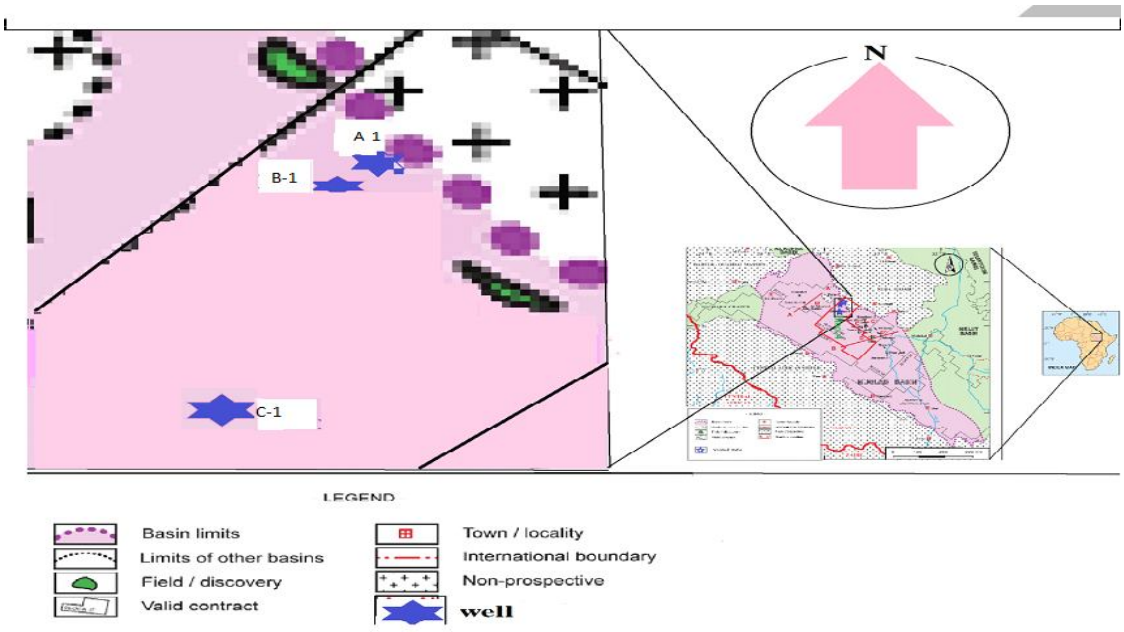

Fig. 1: Location Map of the Study Area

OBJECTIVES OF THE STUDY

The overall objective of the present study was to evaluate the quantity, maturity and quality of the organic matter in the source rock of the study area pertaining to the oil and gas, while the specific objectives was to carry out the following:

- Evaluation of the source rock in the study area by using the available data (geological and geochemical) and geochemical evaluation methods.

- Correlation Model of the exploration wells in the study area by using the geological–geochemical section to determine the generation of the oil window.

STRATIGRAPHY

Hydrocarbon exploration in the Muglad Basin commenced in the early 1970s. Chevron and partners delineated a large basinal area, which extends about 800km in length and 200km in width. Several sub-basinal have been recognized, whereas half-graben structures dominate the tectonic style. The maximum sediment thickness in the Muglad Basin, which was determined seismically, reaches about 15km thick in the deepest troughs comprising the three depositional cycles related to the three rift phases. Table 2 shows the main stratigraphic units in the Muglad area are: Holocene to recent.

- The Tertiary - Quaternary sediment of Um Rawaba Formation.
- Late Jurassic / Early Cretaceous -Tertiary strata.
- The Precambrian Basement Complex.

THE PRECAMBRIAN BASEMENT COMPLEX

The basement rocks bordering towards the NE and SW constitute the elevated shoulders of the Muglad basin these rocks are part of the Sudanese shield and comprise of a metamorphic terrain intruded by localized igneous bodies. These metamorphic rocks date back to the Archean Era. They experienced multiple deformation and reworking phases through their evolution and that ended with the Pan African Tectono Thermal Episode (Schandelmeier et al., 1987) at about 550 Ma. The basement rocks were penetrated and cored in two wells within the NW Muglad area, in Baraka-1 and Adila-1 wells. At these localities the primary composition is granitic and granodioritic gneisses which have been dated as 540±40 Ma (Schull, 1988).

THE LATE JURASSIC/ EARLY CRETACEOUS-TERTIARY STRATA

The lower strata (Late Jurassic / Early Cretaceous to Tertiary) in the Muglad Basin are non marine sediments deposited in lakes, deltas, alluvial fans and fluvial environments. Based on the cyclic subdivision of the "Nubian Sandstone" of NW Sudan, the sedimentary rocks of the Muglad Basin belong to the upper or the Nubian Cycle. (Table 1)

The following accounts, which are on the stratigraphy and sedimentology of Late Jurassic / Early Cretaceous -Tertiary strata were summarized after Schull (1988) and Kaska (1989). Kaska (1989) have established five spore / pollen zones for the Early Cretaceous to Tertiary no marine sediments of the central Sudan on which age determination and correlation are made. These zones are: Early Cretaceous, Middle Cretaceous, Late Cretaceous, Early Paleocene and Oligocene / Late Eocene. The discovered flora is related to the Africa-South America (ASA) flora province. As a result to the repeated rifting, subsidence and sedimentation, three coarsening upward cycles have formed. The nature of this deposit was probably the result of a humid climate and lack of external drainage. This unit is estimated to be up to 1830m thick and it is the main source rock in the Muglad basin (Schull, 1988).

THE TERTIARY-QUATERNARY SEDIMENTS OF UMM RAWABA FORMATION

The Tertiary-Quaternary sediments of the Umm Rawaba Formation represent the most widespread formation within the south central Sudan basins. It covers the surface area of the Muglad basin, and consists of unconsolidated to semi-consolidated gravels, sands, clayey sands and clays of fluvial and lacustrine environment, deposited during the Miocene-Paliocene (Elshafie, 1975). The sediments of the Umm Rawaba Formation generally show rapid changes, which make the lateral correlation somewhat difficult (Ahmed, 1983).

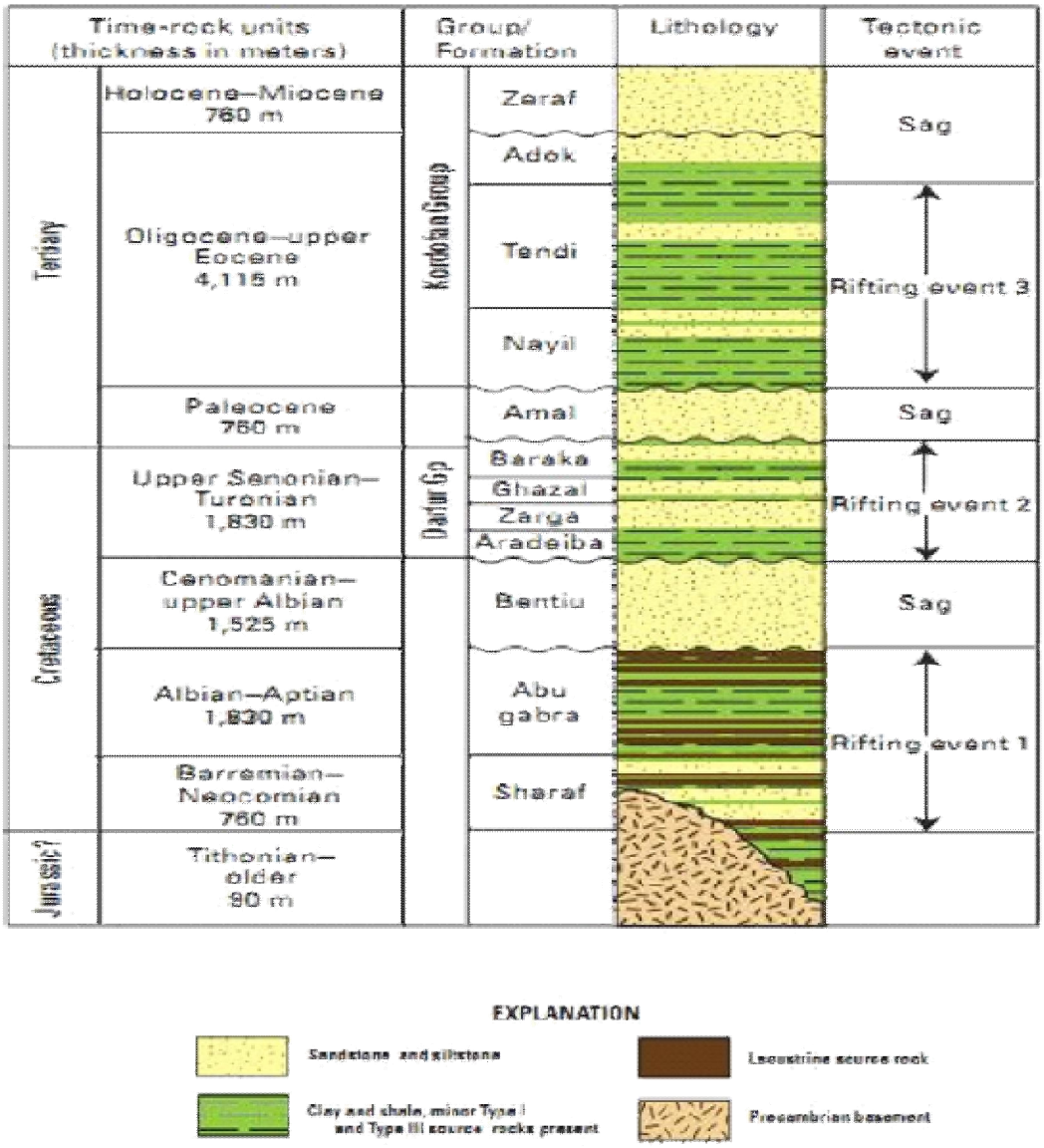

Table 1: Generalized stratigraphic columns for the Muglad Basin, southern Sudan. Modified after Mohamed and others (2000) and Dou and others (2007)

HOLOCENE DEPOSITS

These are unconsolidated sands, clayey sand and black clays, which vary considerably in thickness. Black clays vary in thickness from a few centimeters to over 10 meters and conformably overlie the Umm Rawaba Formation. Wind-blown sand deposits are widely spread in the northwestern part of the muglad Basin.

Fluvial deposits are found along the major drainage systems and are generally composed of sandy and clayey sediments, which sometimes form shallow aquifers. The weathering products along the western side of the Nuba Mountains form narrow bands of washed out debris deposits around the hills (Vail, 1978).

FORMATION		LITHOLOGY AND ENVIRONMENTS	AGE	
KORDOFAN DARFUR GROUP	Zeraf Fm.	Predominantly iron-stained sands and silts with minor claystones interbeds.	Recent-middle Miocene	TERTIARY
	Adik Fm.	Braided streams/alluvial fans.	Oligocene-Late Eocene	
	Tendi Fm.	Predominantly claystone/shale, interbedded with sandstones		
	Nayil Fm.	Fluvial/floodplain & lacustrine		
	Amal Fm.	Predominantly massive medium to coarse sandstones sequences. Braided streams/alluvial fans.	Paleocene	
	Baraka Fm.	Predominantly sandstones with minor shales and claystones interbeds.	Late Senonian Turonian	CRETACEOUS
	Ghazal Fm.	Fluvial/alluvial fans.		
	Zarga Fm.	Predominantly sandstones shales with interbedsof siltstones and sandstones.		
	Aradeiba Fm.	Floodpain/lacustrine with fluvial/deltaic channel sands.		
Bentiu Fm.		Predominantly thick sandstones sequences. Braided/meandering streams.	Cenomanian Late Albian	
Abu Gabra Fm.		Predominantly claystones and shales with fine sandstones and siltstones. Lacustrine/deltaic.	Albian-Aption	
Sharef Fm.		Claystones, shales with interbeds of fine sandstones and siltstones. Lacustrine/fluvial floodplain.	Barremian Neocomian	

Source rocks Reservoir rocks

Table 2: Stratigraphic units of the Muglad rift basin, their lithology and depositional environment (modified after Shull, 1988).

INTERPRETATION

The data obtained from the three well A-1, B-1, and C-1 were analyzed. Geological data include stratigraphical formations, geological ages and lithology. For Geochemical studies, total organic carbon, pyrolysis and vitrinite reflectance studies were carried out.

The A-1 Well

Is a wildcat well and located in Azrag area in the northeast corner of block 4, Muglad Basin. The A-1 well was planned as a vertical well to be drilled to a final total depth of 2766m into Intra Abu Gabra formation. This area is a proven fairway ramp with significant discoveries and established production. The A-1 well was penetrated the Umm Ruwaba, Amal Massive Sand, Baraka, Aradeiba, Bentiu, Abu Gabra and Intra Abu Gabra were encountered while drilling the A-1 well. All Samples indicated the lithologies in this area are mainly sandstone and claystone. The objectives of the well are Abu Gabra-1 and intra Abu Gabra sands as the primary targets while Bentiu sands as the secondary targets. The Geological and Geochemical informations are

represented in Fig (2), Table (3), and Table (4). And in this section we just shed light on the highly important formations with identify and evaluate the main source rock in this well.

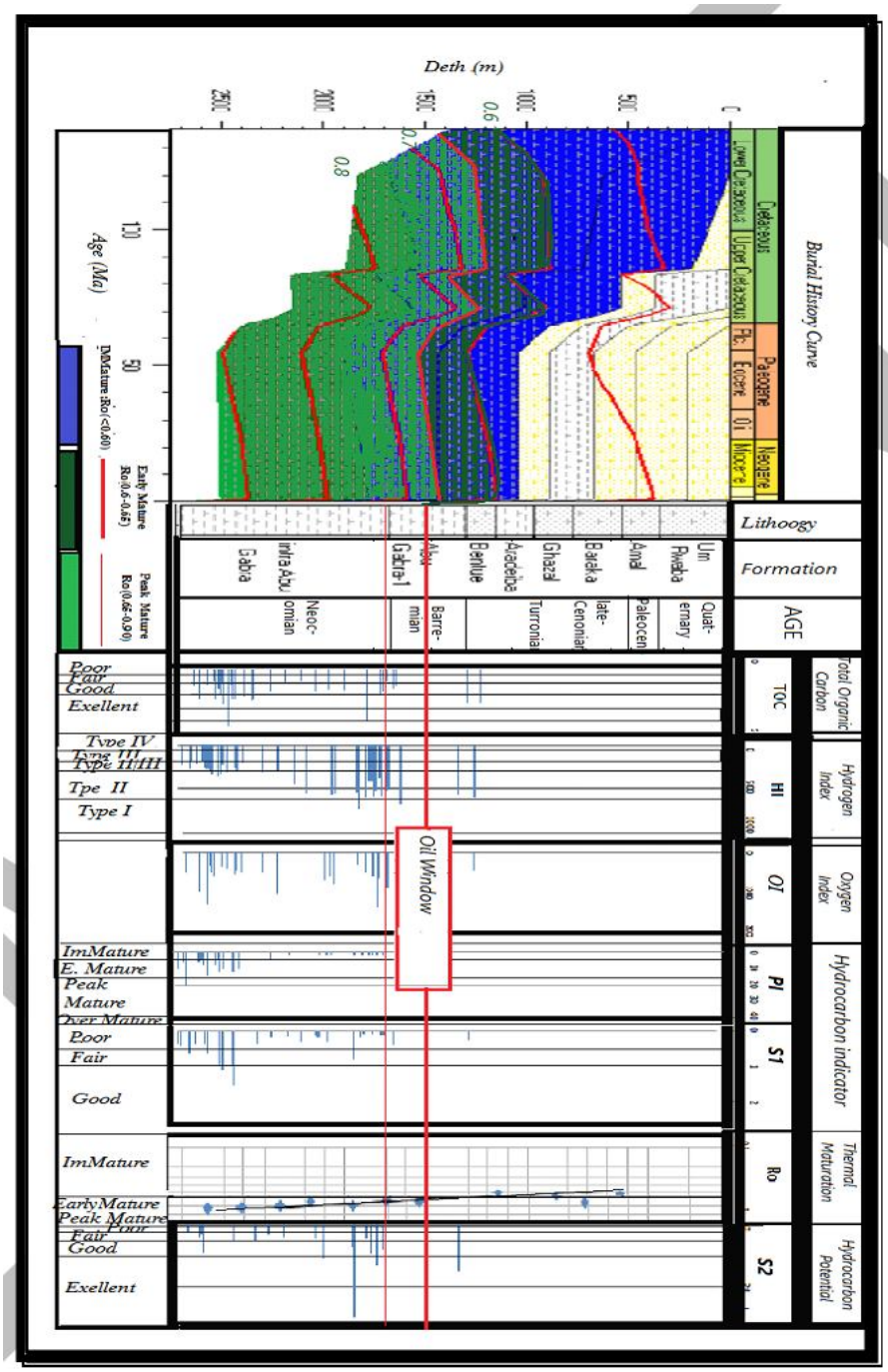

Fig. 2: Burial History Curve Paleotectonic – Geochemical Section for the A-1 Well (Abu Gabra Formation).

Table 3: Show Rock-Eval Data for A-1 Well (from CPL, 2011).

No	Depth (m)	TOC (%)	S_1(mgHC/g) rock	S_2(mgHC/g) rock	S_3(mgCo_2/g) rock	HI	OI	PI S_1/S_1+S_2
1	1250	2.61	0.10	15.96	0.60	612	23	0.01
2	1328	2.65	0.12	15.16	0.54	571	20	0.01
3	1640	3.06	0.15	20.66	0.64	675	21	0.01
4	1690	1.33	.04	6.78	0.61	511	46	0.01
5	1700	1.54	0.04	8.04	0.58	521	38	0.01
6	1730	2.26	0.12	13.45	0.74	595	33	0.01
7	1740	0.92	0.03	3.51	0.64	381	69	0.01
8	1760	1.84	0.08	9.67	0.56	526	31	0.01
9	1770	2.08	0.07	12.33	0.64	593	31	0.01
10	1780	1.16	0.03	4.75	0.66	411	57	0.01
11	1800	2.06	0.06	12.82	0.54	621	26	0.01
12	1835	4.06	0.30	30.01	0.63	739	16	0.01
13	1845	1.34	0.07	7.32	0.65	547	48	0.01
14	1960	1.73	0.12	9.74	0.69	563	40	0.01
15	1980	1.87	0.12	10.86	0.57	581	31	0.01
16	2020	1.59	0.06	8.24	0.57	518	36	0.01
17	2025	1.06	0.04	4.60	0.56	435	53	0.01
18	2100	1.84	0.11	10.36	0.58	561	32	0.01
19	2170	0.94	0.05	4.29	0.46	456	49	0.01
20	2255	1.09	0.07	3.41	0.55	314	51	0.02
21	2325	1.77	0.14	5.73	0.44	324	25	0.02
22	2420	2.42	0.28	5.20	0.47	215	19	0.05
23	2425	2.48	0.33	5.00	0.62	201	25	0.06
24	2455	2.73	0.58	8.45	0.62	310	23	0.06
25	2465	2.15	0.37	5.56	0.60	259	28	0.06
26	2510	2.40	0.42	7.84	0.52	326	22	0.05
27	2530	2.34	0.36	5.70	0.43	244	18	0.06
28	2535	1.26	0.09	4.29	0.56	341	44	0.02
29	2550	4.44	0.77	16.47	0.36	371	8	0.04
30	2575	2.72	0.50	9.06	0.36	333	13	0.05
31	2585	1.05	0.24	3.19	0.33	303	31	0.07
32	2590	1.93	0.29	5.33	0.39	276	20	0.05
33	2600	1.49	0.15	3.97	0.38	267	26	0.04
34	2610	2.43	0.13	6.45	0.42	265	17	0.02
35	2620	0.90	0.05	1,64	0.59	182	65	0.03
36	2655	1.25	0.14	2.89	0.61	232	49	0.05
37	2680	1.14	0.24	2.25	0.40	198	35	0.10
38	2695	2.41	0.17	6.52	0.40	270	17	0.03
39	2725	1.34	0.16	3.17	0.34	236	25	0.05
40	2740	0.31	0.14	0.82	0.24	263	75	0.14

Bentiu Formation

In the A-1 well, Bentiu Formation represents 151m thickness and depth from 1169m-1320m. The geological age of this formation it is Albian to Cenomanian age. And the formation is dominated by sandstone with thin claystone beds interbedded. The TOC content of this formation in the lower part is very good richness (2.61%), and the S_2 value represent good source rock potential in this interval (15.96), pyrolysis (HI) value equal 612 and kerogen types are type I and type II (oil-prone) and the maturity of this formation in this interval is considered immature source rock depended on vitrinite reflectance R_0 which equal 0.52%.

Abu Gabra-1 Formation

The Abu Gabra Formation has 380m thickness and depth range from 1320m-1700m, the geological age of this formation it is Barremian age and this formation is dominated by sandstone with claystoneinterbedded. The TOC values in this formation ranges from 1.33% to 3.06% indicate good to very good organic richness, and the hydrocarbon generating potential values (S_2) range from 6.78-20.66 represent good source rock potential, the Hydrogen Index (HI) values range from 511-675 which are characteristic of type I and type II kerogen (oil-prone) Fig (3), the R_0 equal 0.65% which indicated to mature source rock.

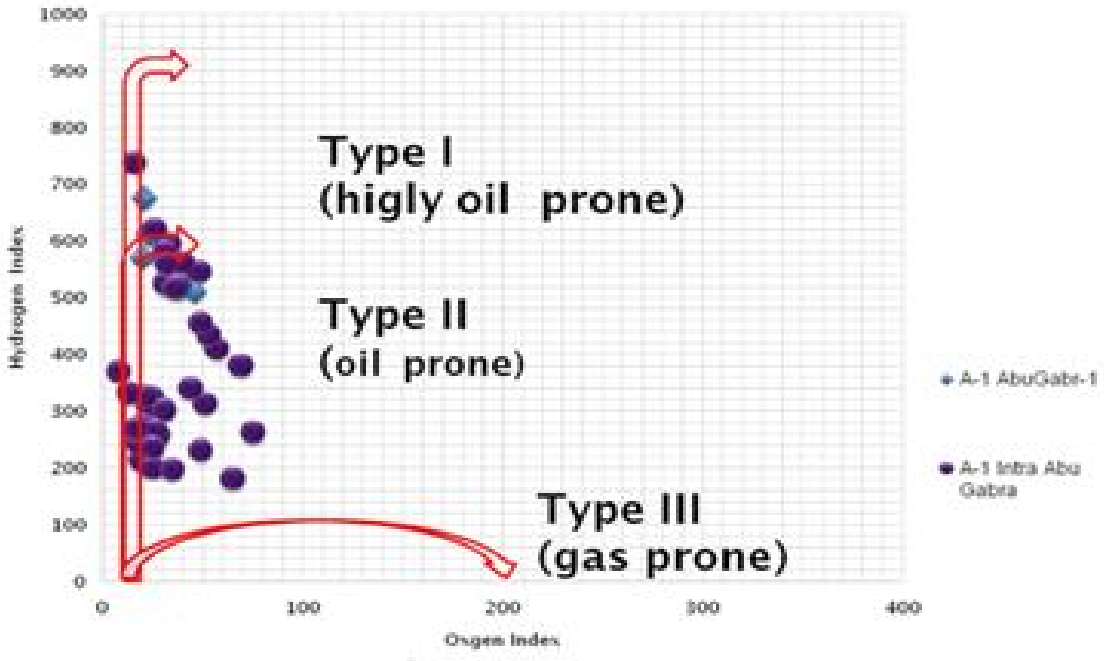

Fig. 3: Hydrogen index/Oxygen index Plot for the A-1Well.

Intra Abu Gabra Formation

This formation is composed mainly of sandstone interbeded with claystone, and is represented the oldest sediments in the A-1 well and exist between 1700m-1766m depth, it has 1066m thickness. The total organic carbon (TOC) content of this formation ranges from 0.90% - 4.44% represent fair to very good organic richness, the Hydrogen Index (HI) values range from (201 - 621) and the kerogen types are type II and type I (oil-prone) Fig (3). The hydrocarbon generating potential (S_2) values range from 0.82 – 30.01 represent poor to good source rock potential, and the vitrinite reflectance R_0 values range from 0.64% – 0.73% which indicate to mature source rock.
VR_0. Reading's %

Table 4: Show Vitrinite Reflectance Readings for A-1 Well (from CPL, 2011).

No	Sample Depth(m)	Min%	Max%	Mean%	No. of reading
1	640	0.40	0.62	0.51	6
2	825	0.64	0.71	0.68	3
3	965	0.54	0.61	0.58	4
4	1250	0.43	0.61	0.52	4
5	1640	0.55	0.71	0.63	8
6	1800	0.52	0.72	0.62	8
7	1960	0.76	0.60	0.68	6
8	2170	0.55	0.76	0.66	15
9	2325	0.52	0.86	0.69	42
10	2510	0.56	0.88	0.72	26
11	2680	0.59	0.91	0.75	11

The B-1 Well

The B-1 well was drilled as a vertical well to a total depth of 2115m as wildcat located in the Azrag area of Block 4, Muglad Basin. The area is proven fair way discoveries and established production. The formations were encountered while drilling the B-1 well includes:

Umm Ruwaba, Ghazal, Zarga/Fault, Aradeiba, Bentiu, Top Abu Gabra, Abu Gabra4 formations. Samples indicated the lithologies in this area are mainly sandstone interbedded with claystone. The objectives of the well are Abu Gabra 4 and Lower Abu Gabra sands (primary objectives) and Abu Gabra sands (secondary objectives). The Geological and Geochemical informations are represented in Fig (4), Table (5), and Table (6). Because the geochemical data available to evaluate source rock is all concentrated on the Abu Gabra formation, we just shed light on it to identify and evaluate it as the highly important formation.

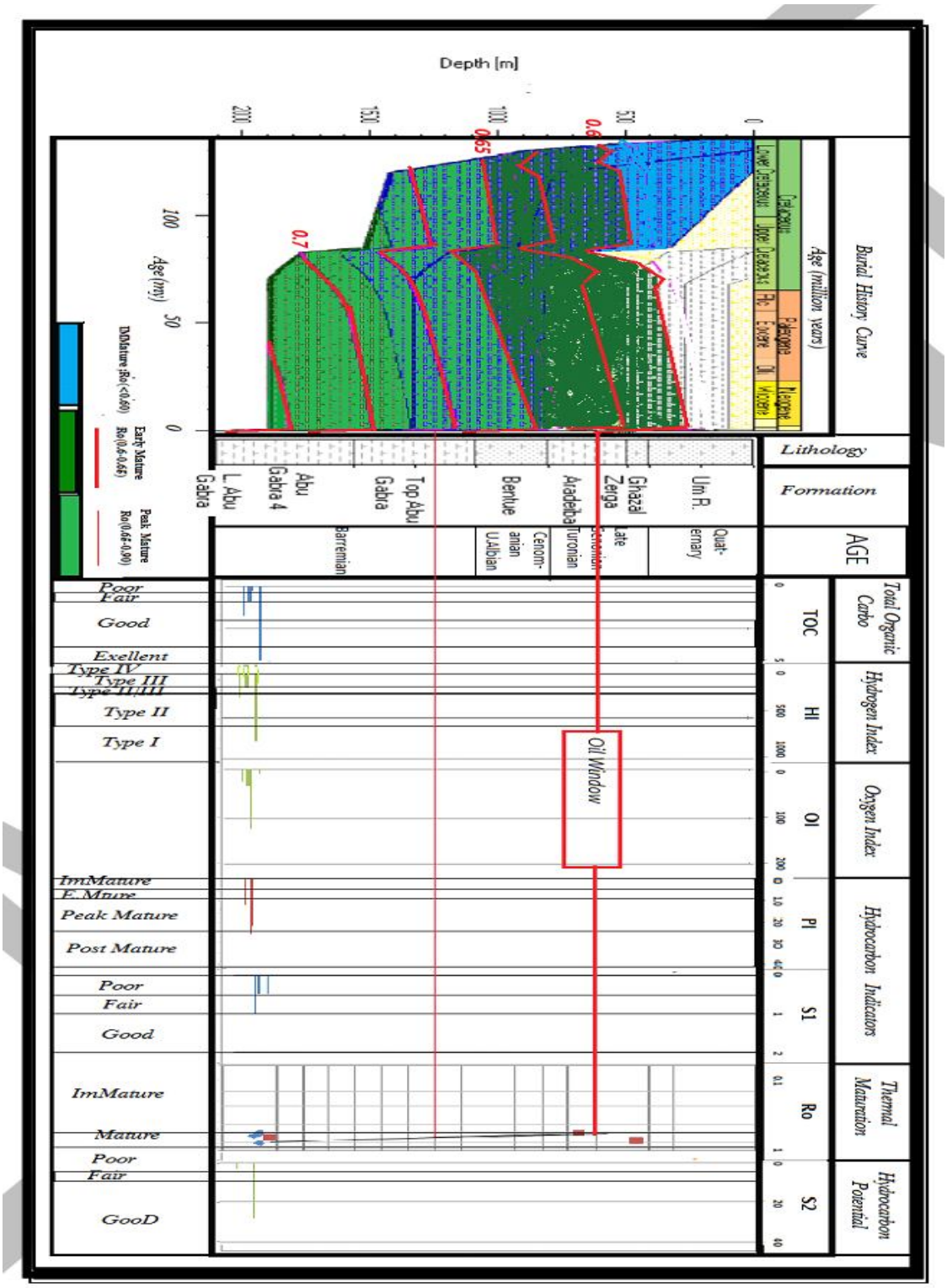

Figure 4: Burial History Curve Paleotectonic – Geochemical Section For the B-1 Well (Abu Gabra Formation).

Table 5: Show Rock-Eval Data for B-1 Well (from CPL, 2011).

No	Depth (m)	TOC (%)	S_1(mgHC/g) rock)	S_2(mgHC/g rock)	S_3(mgCO_2/g) rock)	HI	OI	PI S_1/S_1+S_2
1	1825	0.87	0.01	2.81	0.40	324	46	0.00
2	1859	0.06	0.01	0.04	0.40	72	651	0.11
3	1860	0.17	0.01	0.04	0.32	22	185	0.13
4	1880	0.34	0.02	0.36	0.45	108	135	0.06
5	1955	0.06	0.00	0.04	0.31	70	490	0.08

Abu Gabra Formation

In the B-1 well Abu Gabra formation has 554m thickness and exists from 1561m to 2115m depth. This Formation is composed mainly of Sandstone interbeded with Claystone and Siltstone, the amount of TOC of this formation range from 0.06% to 0.87% however this formation is consider poor to fair organic richness, the S_2 values range from 0.04 – 2.81 represent poor to fair source rock potential, the pyrolysis (HI) values range from 108 – 324 and the kerogen types are type III (gas-prone) and type II (oil-prone) Fig (5), the vitrinite reflectance R_0 equal 0.78% which indicate to mature source rock. VR_0. Reading's %

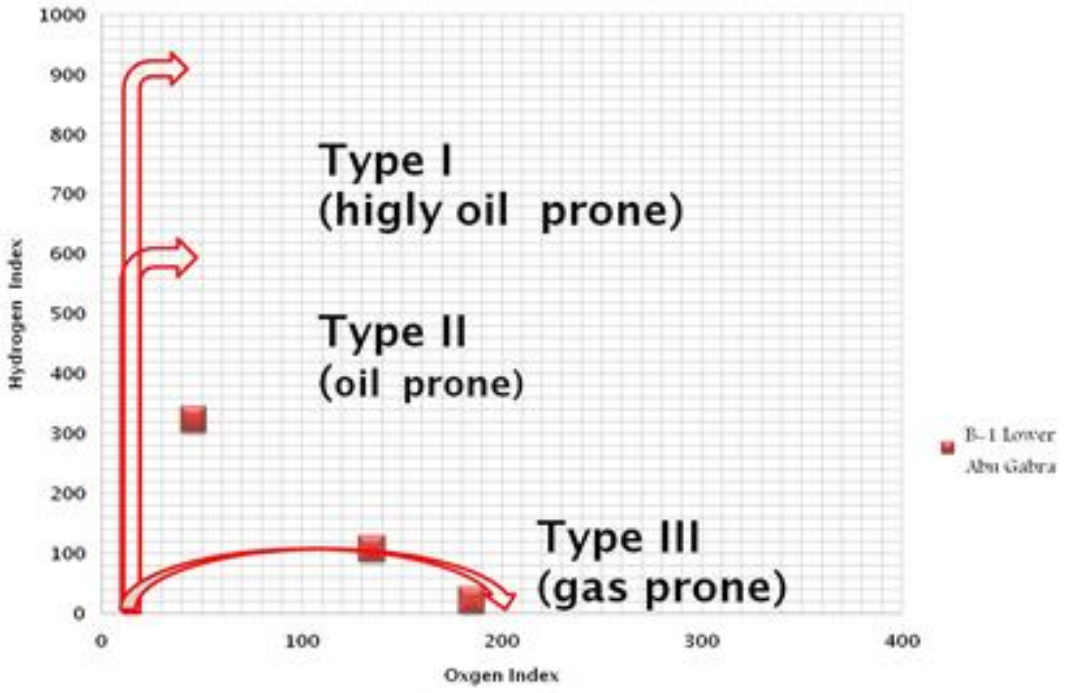

Figure 5: Hydrogen index/Oxygen index Plot for The B-1 Well.

Table 6: Show Vitrinite Reflectance Readings for B-1 Well (from CPL, 2011).

No	Sample Depth(m)	Min%	Max%	Mean%	No. of reading
1	200	/	/	/	/
2	450	0.760	0.971	0.866	9
3	660	0.618	0.806	0.712	7
4	1825	0.689	0.913	0.801	4
5	1955	/	/	/	/

The C-1 well

It is proposed as an appraisal well to test the reservoir continuity of the north extension of the proven oil in the Azrag area, Kikang4A Muglad Basin. The well located approximately 13 km NNE of greater Neem production field, the well is reached final total depth 2800m, and penetrated the Amal, Baraka, Ghazal, Bentiu, Abu Gabra, Intra Abu Gabra-1 and Intra Abu Gabra-2 formations while drilling the C-1 well. Samples indicated the lithologies in this area are mainly sandstone interbedded with claystone.

The primary objective of this well is Intra Abu Gabra 1 and 2 sands. The Geological and Geochemical information's are represented in Fig (6), Table (7), and Table (8).

Abu Gabra Formation

In the C-1 well Abu Gabra Formation represents 422m thickness and depth from 1084m -1506m. This formation is composed mainly of sandstone interbeded with claystone, the total organic carbon (TOC) content of this formation range from 1.52% to 2.98% represent good to very good organic richness, the Hydrogen Index (HI) values range from 200 to 735 and the kerogen types are type II (mixed gas/ oil- prone) and type I (oil- prone) Fig (7).

The hydrocarbon generating potential (S_2)) values range from 3.04 to 20.76 represent fair to good source rock potential, and the maturity of this formation is considered immature source rock depending on vitrinite reflectance R_0 values which range from 0.48% to 0.59%.

Intra Abu Gabra-1 Formation

This formation is composed mainly of sandstone interbeded with claystone. The formation represents 294m thickness and exists between 1506m to 1800m depth; the TOC content of this formation is range from 1.01% to 3.90% however this formation is indicate to good-very good organic carbon richness, the (S_2) values range from 0.82-30.11 which is represent poor to good source rock potential, the pyrolysis (HI) values range from 240-772 and the kerogen types are type II (mixed gas/ oil- prone) and type I (oil- prone) Fig (7), the vitrinite reflectance R_0 values range from 0.61% to 0.74% which indicate to mature source rock.

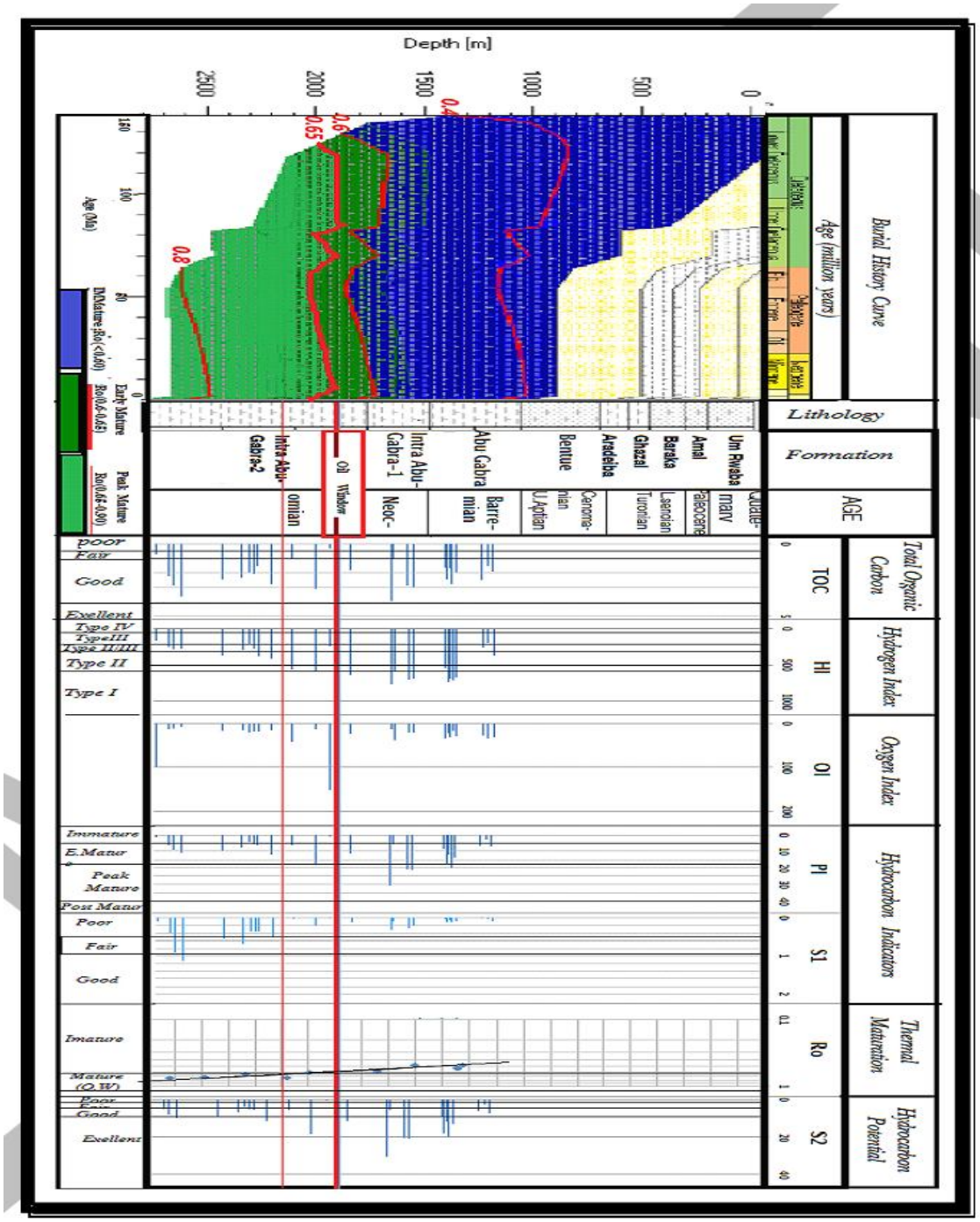

Figure 6: Burial History Curve Palaeotectonic – Geochemical Section for the C-1 Well (Abu Gabra Formation)

Table 7: Show Rock-Eval Data for C-1 Well (from CPL, 2011).

No	Depth (m)	TOC %	S_1(mgHC/g rock)	S_2(mgHC/g rock)	S_3(mgCo_2/g rock)	HI	OI	PI S_1/S_1+S_2
1	1120	1.92	0.09	7.11	0.61	371	32	0.01
2	1140	1.52	0.03	3.04	0.54	200	35	0.01
3	1165	2.45	0.03	6.50	0.67	266	27	0.01
4	1265	2.00	0.08	13.31	0.57	665	29	0.01
5	1280	2.75	0.10	19.69	0.44	716	16	0.01
6	1290	1.72	0.06	11.79	0.53	687	31	0.01
7	1300	2.41	0.11	17.69	0.53	735	22	0.01
8	1310	1.64	0.05	8.82	0.58	538	35	0.01
9	1440	2.98	0.21	20.76	0.64	696	21	0.01
10	1460	2.86	0.27	20.24	0.60	707	21	0.01
11	1520	1.01	0.09	5.89	0.39	584	39	0.01
12	1530	3.90	0.31	30.11	0.50	772	13	0.01
13	1695	1.82	0.11	11.63	0.45	638	24	0.01
14	1780	0.34	0.02	0.82	0.52	240	152	0.02
15	1840	3.07	0.22	18.31	0.39	596	13	0.01
16	1935	1.07	0.05	6.03	0.45	563	42	0.01
17	2020	2.75	0.53	11.50	0.40	418	15	0.04
18	2075	1.56	0.36	6.01	0.29	385	19	0.06
19	2090	2.08	0.36	5.66	0.37	272	18	0.06
20	2110	1.96	0.36	4.19	0.42	214	21	0.08
21	2140	2.37	0.68	6.95	0.33	293	14	0.09
22	2220	2.43	0.54	8.96	0.40	369	16	0.06
23	2390	3.61	1.14	9.94	0.33	276	9	0.10
24	2420	2.86	0.91	8.11	0.31	284	11	0.10
25	2440	2.27	0.41	5.72	0.29	252	13	0.07
26	2490	0.79	0.08	1.40	0.79	177	100	0.05
27	2499	1.53	0.13	4.41	0.48	288	31	0.03

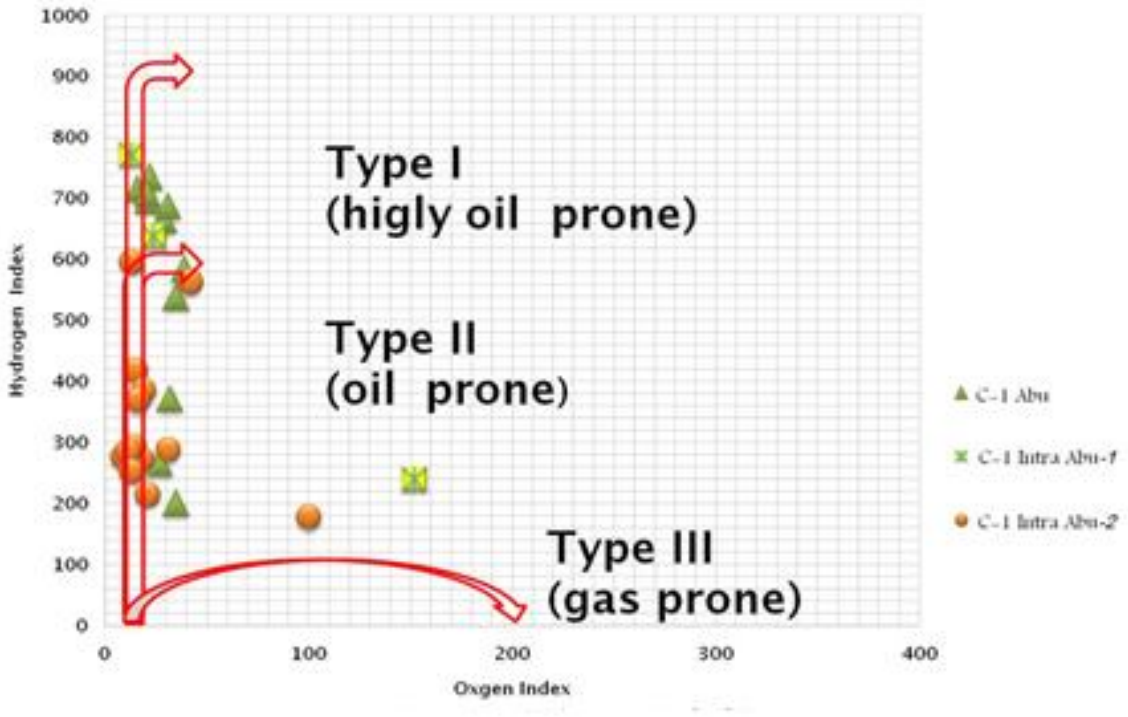

Figure 7: Hydrogen index/Oxygen index Plot for the C-1 Well.

Intra Abu Gabra-2 Formation

The Intra Abu Gabra-2 Formation has 1000m thickness and depth range from 1800m-2800m, and This formation is composed predominantly of claystone intercalated with thin beds of sandstone. The total organic carbon (TOC) amount of this formation range from 0.79%-3.61% represents fair to very good organic carbon richness, the hydrogen index (HI) values range from 214-596 and the kerogen types are type II and type I (oil-prone) Fig (7). The hydrocarbon generating potential (S_2) values range from 4.14 to 18.31 which is indicate to fair-good source rock potential, and the vitrinite reflectance R_0 values range from 0.65% to 0.75% which indicate to mature source rock. VR_0. Reading's %

Table 8: Show Vitrinite Reflectance Readings for C-1 Well (From CPL, 2011).

No	Sample Depth(m)	Min%	Max%	Mean%	No. of reading
1	1120	0.31	0.57	0.44	15
2	1140	0.49	0.60	0.55	12
3	1300	0.48	0.48	0.48	1
4	1440	0.44	0.71	0.58	9
5	1695	0.49	0.75	0.62	8
6	1780	0.63	0.86	0.75	10
7	1935	0.52	0.78	0.65	10
8	2090	0.55	0.83	0.69	20
9	2220	0.58	0.86	0.72	28

SUMMARY

From the Geochemical data interpretation of the A-1 Well (Table- 3), the lower part of the Bentiu Formation represent good source rock potential according to the S_2 values, also Abu Gabra-1 and Intra Abu Gabra Formations represents poor to good source rock potential based on the hydrogen generating potential, the Bentiu formation was not entered oil generation window, Abu Gabra-1 and Intra Abu Gabra formations were entered to zone of oil generation window (Fig -2).

Abu Gabra Formation in the B-1 Well represents poor to fair source rock richness and potential based on TOC and S_2 (Table -4), and this formation was entered oil generation window (Fig -4). In the C-1 Well Abu Gabra and Intra Abu-1 Gabra Formations represents good to very good organic carbon richness and fair to good source rock potential, poor to good source rock potential respectively. Also Intra Abu gabra-2 represent fair to very good richness in organic carbon and fair to good source rock potential (Table -5). Abu Gabra formation was not entered oil generation window, but Intra Abu Gabra-1 and Intra Abu Gabra-2 formations were entered to oil generation window (Fig -6).

RESULTS

From the interpretation of the exploration wells in the study area the lower part of the Bentiu and Abu Gabra-1 formations in the A-1 well were existing oil-prone, and Intra Abu Gabra formation was giving oil+gas-prone, according to the HI and kerogen types.

Abu Gabra Formation in the B-1 well was existing type IV (mainly inert) and type I (oil-prone) kerogens.

The Abu Gabra, Intra Abu Gabra-1 and Intra Abu Gabra-2 Formations in the C-1 well were giving oil+gas-prone based on HI values and kerogen types.

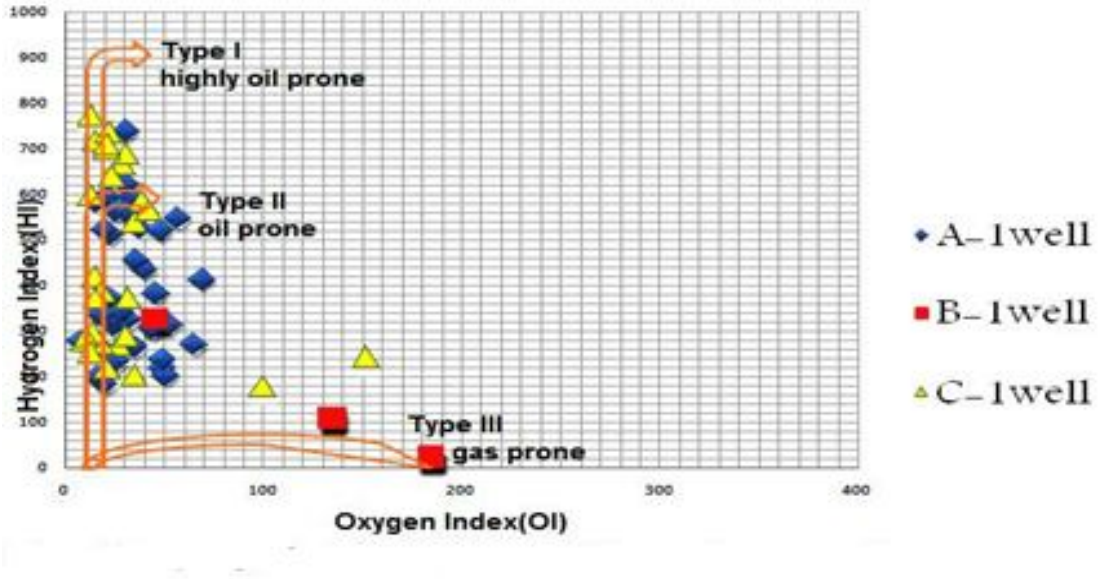

Figure 8: Hydrogen index/Oxygen index Plot for the A-1,B-1 and C-1 Wells.

The Chronological, Maturity Correlation Model of Exploration Wells:

The Chronological, Maturity Correlation Model of Exploration wells has been done by petroMod v11 and paint programs with use informations about wells include the distances between the wells, coordinates, wells depth, stratigraphic formations, geological ages, and lithology.

The correlation model lead to determine the beginning generation of the oil window and its extension between the wells in the study area.

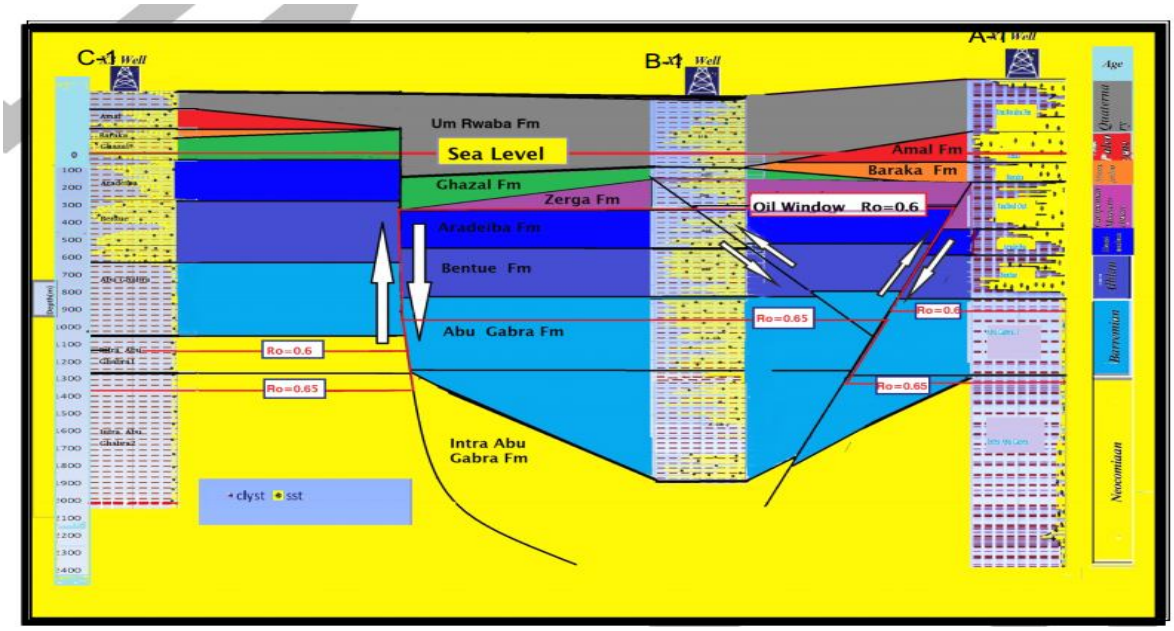

Figure 9: Chronological, Maturity Correlation Between the A-1, B-1 And C-1 Wells.

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